SCIENCE, AERONAUTICS AND TECHNOLOGY
FY 1998 ESTIMATES
BUDGET SUMMARY

OFFICE OF LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS

SUMMARY OF RESOURCE REQUIREMENTS

Life and Microgravity Sciences and Applications	FY 1996	FY 1997	FY 1998
Life sciences			
Research and analysis	55,200	58,000	50,000
[Construction of facilities]	--	--	[2,000]
Flight program	54,400	39,400	35,500
Subtotal	**109,600**	**97,400**	**85,500**
Microgravity science research			
Research and analysis	30,200	31,900	36,500
Flight program	76,300	73,400	64,900
Subtotal	**106,500**	**105,300**	**101,400**
Space product development	26,500	13,000	12,900
Space shuttle/spacelab payload mission management and integration	53,600	24,200	6,900
Aerospace medicine/occupational health	8,000	3,800	7,500
Total	**304,200**	**243,700**	**214,200**

Distribution of Program Amount by Installation	FY 1996	FY 1997	FY 1998
Johnson Space Center	72,900	38,100	37,700
Kennedy Space Center	11,200	7,200	6,400
Marshall Space Flight Center	67,300	49,000	45,800
Ames Research Center	28,900	26,300	21,500
Langley Research Center	4,100	2,700	2,400
Lewis Research Center	53,300	41,000	37,700
Goddard Space Flight Center	1,300	22,200	27,800
Jet Propulsion Laboratory	13,600	16,700	13,800
Headquarters	51,600	40,500	21,100
Total	**304,200**	**243,700**	**214,200**

SCIENCE, AERONAUTICS AND TECHNOLOGY
FISCAL YEAR 1998 ESTIMATES
OFFICE OF LIFE AND MICROGRAVITY SCIENCE AND APPLICATIONS

PROGRAM GOALS

The NASA Life and Microgravity Sciences and Applications (LMSA) program leads the nation's efforts in space biological, physical and chemical research and aerospace medicine, supporting technology development, and applications using the attributes of the space environment to advance knowledge, to improve the quality of life on Earth, and to strengthen the foundations for continuing the exploration and development of space. LMSA activities are supportive of, and closely aligned to, the goals of the Human Exploration and Development of Space (HEDS) Enterprise. Those goals include: 1) increase human knowledge of Nature's processes using the space environment; 2) explore and settle the Solar System; 3) achieve routine space travel; and 4) enrich life on Earth through people living and working in Space.

countermeasures developed versus those which are accepted for operational use.

The LMSA program has adopted the Lead Center management approach and is rapidly moving to implement the Lead Center concept through five major programs. The Johnson Space Center (JSC) will become the Lead Center for two programs; Advanced Human Support Technologies Program and the Biomedical Research Program. The Ames Research Center (ARC) will be the Lead Center for the Gravitational Biology Program. The Marshall Space Flight Center (MSFC) will take Lead Center responsibility for two programs; Microgravity Research and Space Product Development. Johnson Space Center has also been designated the Lead Center for all Space Station activities and is responsible for the cost, schedule and technical performance of the total program, including the LMSA portions of the overall program.

The science components of the Space Station program -- the NASA-Mir Research Program, and Space Station Facilities and Utilization -- are now under the management of the International Space Station program. The funding and budget justification for these activities is now included under the International Space Station (ISS) budget justification.

The Research and Analysis activities within the LMSA program support ground-based research and definition studies upon which flight experiments are based. The flight programs in LMSA develop experiments to fly on suborbital rockets, parabolic aircraft, and orbiting spacecraft such as the Space Shuttle, the Mir Space Station and the International Space Station (ISS). Strategic direction, budget development, and advocacy, liaison and outreach for all of these experiments, as well as for additional attached Space Shuttle payloads developed by other NASA organizations, is conducted through NASA Headquarters. LMSA also develops the research requirements for the Space Station Research Program. LMSA is also responsible for maintaining the health and productivity of astronauts and developing requirements for medical operations and research.

The Life Sciences Research and Analysis program supports ground-based research and definition studies in six major areas; (1) Space Physiology and Countermeasures, (2) Space Human Factors Engineering, (3) Environmental Health, (4) Space Radiation Health, (5) Advanced Life Support, and (6) Space Biology. The Research and Analysis program also includes data archiving, laboratories, NASA Specialized Centers of Research and Training (NSCORTs), and joint activities with the National Institutes of Health (NIH) and the National Science Foundation (NSF). Ground-based research relies on such unique gravitational simulation facilities such as centrifuges.

The Life Sciences Flight program, consists of the Flight Experiments Program, the NASA/Mir Research Program (NMRP), the Space Station Science Utilization Program and other international cooperative efforts. The flight experiments program selects, defines, develops and conducts in-space medical and biological research, and tests advanced life

support and extravehicular technologies. It works closely with the scientific community to develop a broad variety of multi-user research facilities designed to support the life sciences community's needs of the future.

The Microgravity Research and Analysis program supports ground-based research and definition studies for flight experiment candidates in five primary areas: (1) Biotechnology, (2) Combustion Science, (3) Fluid Physics and Transport Phenomena, 4) Fundamental Physics, and 5) Materials Science. Ground-based research facilities include laboratories, drop-tubes, and drop towers.

The Microgravity Flight program, consisting of the Flight Experiments Program, the NASA/Mir Research Program (NMRP) and the Space Station Science Utilization Program, provides a wide range of experimental capabilities. The flight program supports a broad variety of hardware experiments including both unique scientific experiments as well as multi-user research facilities. These flight experiments will serve as the cornerstone of microgravity and applications research in the future. Experiments are principally flown utilizing sounding rockets, parabolic aircraft, the Space Shuttle, the Mir Space Station, and/or other commercially-developed spacecraft.

The Space Shuttle/Spacelab Mission Management and Integration program performs the mission planning, integration and execution of all NASA/Spacelab, the NASA-Mir Research Program (NMRP) and attached Space Shuttle payloads. The program integrates the scientific payloads into the various carriers, trains payload specialists, and performs system management and engineering development of flight equipment and software.

The Aerospace Medicine and Occupational Health program is responsible for development of policies and requirements to maintain and provide medical support to optimize the health, safety and productivity of our astronauts in space, and to protect and promote the health and safety of all NASA employees. The program also develops technologies and applications including telemedicine and global health applications.

The Space Product Development program is now reflected in the LMSA program amounts. This program's budget was previously justified under the Space Access & Technology program. The Space Product Development program facilitates the use of space for commercial products and services through the creation of Commercial Space Centers and industry partnerships that provide expertise and access to NASA experiment facilities as well as access to space.

A review of the financial status of the LMSA program at the end of FY 1996 revealed that significant unobligated and uncosted balances existed within the program. These balances were found to have been built up over the last few years, and resulted for a variety of reasons. The existence of these balances has allowed the program to transfer FY 1996 and FY 1997 funding

to Space Station development activities, as detailed in the revisions to these respective operating plans and the "FY 1997 Changes" section of this budget justification, as well as refocus some baseline research activities as described in the following budget justification. We expect these balances to be within agency thresholds, now under development, for this type of research program by the end of FY 1997.

LIFE SCIENCES RESEARCH AND ANALYSIS

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
Life sciences research and analysis	55,200	58,000	50,000
[Construction of facilities]	--	--	[2,000]

PROGRAM GOALS

The Life Sciences Research and Analysis (R&A) program sponsors basic and applied research in biomedicine, biology, environmental science, and related technologies in support of the Agency's strategic goals. The program goals are: 1) to effectively utilize gravity, microgravity and other characteristics of the space environment to enhance our understanding of fundamental biological processes; 2) to develop the scientific and technological foundations for a safe, productive human presence in space for extended periods of time; and 3) to apply this knowledge and technology to improve our Nation's competitiveness, education, and the quality of life on Earth.

The Life Sciences Research and Analysis program supports applied research as well as basic research. Its basic research activities use the unique weightless environment of space as a tool to learn about basic structures and functions of humans, other animals, and plants. Its applied research activities enable the development of procedures or countermeasures to prevent the undesirable effects of space flight on humans. Life Sciences Research and Analysis pursues its goals through ground-based research programs and projects at universities, NASA Centers, nonprofit and industrial organizations, and other Federal agencies. It also finances specialized support facilities and technologies in support of the science community.

The Life Sciences Research and Analysis budget supports ground-based research in the following three programs: (1) biomedical research and countermeasures; (2) gravitational biology; and (3) advanced human support technology. The biomedical research and countermeasures program includes physiology, environmental health, radiation health, and behavior and performance. The gravitational biology program includes cell and molecular biology, developmental biology, and comparative and plant biology. The advanced human

support technology program consists of advanced life support, advanced extravehicular activity systems, advanced environmental monitoring and controls, human factors engineering, and radiation shielding.

Research and Analysis also sponsors additional specialized activities and services. Its advanced technology development activities respond to the defined needs of the space life sciences ground-based and flight programs. The life sciences education and outreach activity informs the professional community about space life sciences findings and activities, encourages students of all ages to consider careers in space life sciences, and sponsors development programs aimed at those already engaged in life sciences research careers.

All Research and Analysis investigations that the Life Sciences Division sponsors are peer-reviewed. The program's research solicitations and peer review program are administered from Headquarters, and proposals submitted by NASA Field Center researchers are subjected to the same rigorous competitive standards as those of extramural researchers. Life Sciences' policies permit peer reviews of selected proposals to be performed under cooperative arrangements with the NIH.

STRATEGY FOR ACHIEVING GOALS

The Life Sciences research and analysis program biomedical research and countermeasures research that seeks to characterize and determine the mechanisms of physiological changes in weightlessness, including those that threaten to limit the duration of human space missions. It also develops methods that allow humans to live and work in microgravity, that optimize crew safety, well-being, and performance, and that minimize the deleterious effects of returning to Earth's gravity after spaceflight. It attempts to specify, measure, and control spacecraft environments, and it develops standards and countermeasures, where necessary, to optimize crew health, safety, and productivity. The program develops monitoring techniques, procedures, and standards for extended missions. It also seeks to establish the scientific basis for protecting humans engaged in the development and exploration of space from radiation hazards.

The program also seeks to improve understanding of the role of gravity in biological processes by using a variety of gravitational environments as research tools or by determining the combined effects of gravity and other environmental factors on biological systems. The program emphasizes research in cell and molecular biology, developmental biology, and comparative and plant biology. Its research includes plants, animals, or other organisms as subjects, as well as cell or tissue cultures.

Additionally, the research and analysis program develops advanced regenerative life support technologies and systems by combining biological, physical, and chemical processes capable of producing and recycling the food, air, and water needed to support long-term human

missions in space in a safe and reliable manner while minimizing the need for resupply. Its projects and activities apply engineering sciences to the design of technologies that support and control physical-chemical and bioregenerative closed loop systems for clean air and potable water. The program applies knowledge from the life sciences to develop technologies for growing, harvesting, and processing crop plants for flight crew consumption. The advanced extravehicular activity (EVA) systems program develops new technologies necessary to perform EVAs productively, safely, and efficiently during future long-duration missions. EVA systems are defined as the operational hardware and operational procedures that allow safe, efficient, and productive crew activities in the proximity of a planetary habitat, a spacecraft, or an orbiting station. EVA hardware includes space suits, portable life support systems, and items such as foot restraints, tools, work stations, and interfaces. These items, along with operational procedures and protocols, are candidates for advanced EVA systems technology development.

Space human factors pursues multiple objectives. It works to expand knowledge of human psychological and physical capabilities and limitations in space. It develops technologies that integrate the human and system elements of space flight. It encourages mission planners to use human factors research results and technology developments to improve mission results and crew safety. The program makes NASA technologies available to the private sector for Earth applications.

The Advanced Technology Development (ATD) project sponsors multidisciplinary technology development activities that enhance the capability, reliability and quality of Life Sciences flight hardware. The program solves technical problems that currently limit science return from existing flight equipment. It enables new types of scientific investigations in space; promotes technology transfer of Life Sciences technology to industry; and establishes partnerships with industry, universities, and other agencies.

Center Support

The Life Sciences Research and Analysis (R&A) program currently manages its projects, activities, and tasks from Headquarters and the Ames Research Center (ARC), the Johnson Space Center (JSC), and the Kennedy Space Center (KSC). The program is actively working to implement the Lead Center program management approach and will be formally assigning lead center responsibility to both JSC and ARC. JSC will be the lead center for the Biomedical Research Program and the Advanced Human Support Technologies Program. ARC will be assigned responsibility for the Gravitational Biology Program. The R & A program also draws upon other Centers on occasion to administer tasks or for other unique expertise. Following the program's adoption of revised peer review procedures during FY 1994, the Life Sciences program returned the responsibility for grants peer review and selection for funding to Headquarters. As a result, all proposals selected for funding, both those submitted by extramural investigators as well as those from intramural researchers at NASA Centers, must

withstand a Headquarters-managed, competitive selection process. Effective in FY 1997, grant awards made to extramural investigators are being administered by the Goddard Space Flight Center (GSFC), which is now providing grants administration support to Headquarters science programs.

NIH Cooperation

Within Life Sciences, $10.0 million each year supports collaborative activities with the NIH, of which more than $5.0 million is supported under the Research and Analysis program. NASA/Life Sciences resources dedicated to joint NASA/NIH collaboration are likely to increase in future years, stimulated both by the success of past collaborative efforts and by the recommendations of the NASA/NIH Interagency Advisory Committee. A key collaborative venture between NASA and NIH is the Human Brain project, an activity which concentrates on neural science and informatics research. NASA and NIH will continue to provide mutual support to a NASA/NIH Specialized Center of Research and Technology (NSCORT) for Vestibular Research at Northwestern Medical Center in Chicago. A sampling of other collaborative research and technology projects that NASA Life Sciences has underway with NIH include several projects in cancer research, including a technology development task which aims to develop advanced digital mammography techniques. NASA and the National Cancer Institute (NCI) are jointly supporting radiation biology research into the fundamental processes leading to cancer. This research will provide benefits for extended space flight and occupational health. NASA and NIH are working together on neurological and behavioral sciences research, developmental physiology and human development research, cardiovascular, pulmonary, and hematologic systems research, and the application of remote sensing satellites to predict and control human disease. The two agencies are supporting several activities designed to enhance the electronic information services available to life sciences researchers. For example, SPACELINE, an on-line bibliographic database of space life sciences developed in collaboration with the National Library of Medicine (NLM), recently became available for use.

Other Collaborative Activities

The objective of establishing a strong radiobiology program at Loma Linda University Medical Center began during FY 1996 and will continue during FY 1997. Congressional action provided $4.5 million of FY 1996 resources for this purpose, and follow-on Congressional action has designated the application of an additional $4.0 million from FY 1997 appropriations. During FY 1996, Life Sciences initiated a cooperative agreement with the Loma Linda University that will support up to 400 hours of proton beam time and core support for proton research at Loma Linda University. The University is constructing a building containing laboratory space dedicated to the radiobiology program. In FY 1997, LMSA plans to initiate a cooperative effort with the Cleveland Clinic in cardiac imagery activities. Definition of this activity is underway.

Life Sciences also participates with other Federal agencies such as the Department of Energy (DOE), the Department of Defense (DOD) and a variety of other national and international organizations whose research interests intersect those of the Research and Analysis program. These organizations include the National Science Foundation, the American Society for Gravitational and Space Biology (ASGSB), the Aerospace Medical Association (AMA), and the American College of Sports Medicine (ACSM). The program also reaches out to groups whose members are underrepresented in the life sciences research community, such as the Alaska Native Association (ANA).

MEASURES OF PERFORMANCE

	FY 1996 Plan	FY 1996 Actual	FY 1997 Plan	FY 1997 Revised	FY 1998 Plan	Description
Number of Ground Principal Investigators	224	210	232	200	200	--
Number of Co-Investigators supported (Ground-Based and Flight)	291	300	302	290	290	--
Number of Refereed Publications (Ground-Based and Flight)	540	540	600	525	525	--
Release Life Sciences NASA Research Announcements	1st Qtr FY 1996	2nd Qtr FY 1996	1st Qtr FY 1997	2nd Qtr FY 1997	2nd Qtr FY 1998	Ensure a steady source of peer-reviewed research and development tasks
Initiate 5-year performance period for new NSCORTS	3rd Qtr FY 1996	3rd Qtr FY 1996	3rd Qtr FY 1997	--	--	New NSCORTS in Gravitational Biology and Bioregenerative Life Support were selected in FY 1996. New Radiation Health NSCORT due for selection during third quarter FY 1997.

ACCOMPLISHMENTS AND PLANS

The Research and Analysis program is taking steps to improve the quality of its research selections and to increase the budgetary resources that it makes available to research investigators. Forty-seven research proposals selected in FY 1996 received multi-year research awards valued at approximately $15 million through FY 1998. The NASA/Life Sciences hopes to award a comparable number during FY 1997 and during FY 1998. All awards will derive from proposals submitted in response to the NASA's competitive selection and peer review procedures. Additionally, the FY 1997 and FY 1998 program activities will include increased activity in areas of collaboration with other federal agencies and non-federal organizations, notably in the area of radiation health. A number of Life Sciences' collaborative and technology development activities have already begun yielding benefits in ground-based applications and should continue to do so through FY 1998.

During FY 1997 and FY 1998, the space physiology and countermeasures activities will concentrate on the problems associated with extended stays in space, especially stays of 90 days to 180 days, in preparation for the ISS era. Studies may include human and animal subjects. Budgetary resources will support both basic and applied research on the effects of hypogravity and hypergravity. The project will seek new techniques for the non-invasive, in-flight measurement of the variables that characterize all systems. It will also address the development of an optimal exercise protocol for space flight to provide comprehensive countermeasures to the various physiological and psychological systems, including cardiovascular, musculoskeletal, neuromuscular function, fluid and electrolyte balance, and performance, while minimizing demands on crew time.

During FY 1997 and FY 1998, the space biology efforts will maintain focus on advancing fundamental knowledge in the biological sciences using the tool of gravity and microgravity. Investigations, including renewals and new awards, will concentrate on the areas of cell biology, developmental biology, and comparative and plant biology. Cell biology investigations will examine how gravitational information is transduced, how cells respond to acute and long-term variations in gravity, and how gravity affects the composition, size, shape, and function of cells. Developmental biology investigations will study the influence of gravity and microgravity on animal growth, development, reproduction, genetic integrity, life span, senescence, and subsequent generations of animals. Comparative and plant biology will conduct research to understand how animals and plants perceive, transduce, and respond to gravitational force. The investigations will elucidate the role of hypergravity and microgravity in developmental and reproductive processes and will seek to understand the role of hypergravity and microgravity in such areas as the metabolism and transport processes in animals and plants.

The environmental systems and technologies tasks will refocus their ground-based activities during FY 1997 and FY 1998 toward the development of technologies that will not only support specific needs during the ISS era, but also addresses the strategic thrusts of the Human Exploration and Development of Space Enterprise. Life Sciences environmental systems and technologies programs include the environmental health program, the radiation health program, the space human factors program, the advanced life support and advanced EVA programs, and the Advanced Technology Development (ATD) program.

The environmental health activities will conduct research that will help to establish space flight environmental standards for human health and performance. The project will use FY 1997 and FY 1998 resources to define physiological norms for atmospheric gases, identify toxicants and describe microbial populations (including their numbers, pathogenicity, or products). The program will emphasize investigations of optimal nitrogen washout protocols, and it will rely upon ground-based studies to anticipate the effects of closed systems in space.

During FY 1997 and FY 1998, the radiation health project will support ground-based experimental radiobiology studies using proton and high-energy heavy ion beams. FY 1997 and FY 1998 resources will support studies attempting to understand the mechanisms responsible for radiation-caused carcinogenesis and the reliability of interspecies extrapolation of radiobiological effects. The radiation health program initiated a new collaborative venture with the National Cancer Institute during FY 1996 that will continue during the budget period. This new NASA/National Cancer Institute (NCI) collaborative effort will provide up to $2.0 million per year of research funding through FY 2000, with each agency contributing equally. The collaborative project will attempt to define and understand the nature and extent of long-term genomic instability in mammalian cells caused by chronic low-dose radiation exposures of the kind likely to be encountered during extended space flight and in certain occupational settings. The radiation health project has also approved a series of accelerator 'missions' at the Brookhaven National Laboratory, using the Alternating Gradient Synchrotron. These 'missions' will take place during FY 1997 and FY 1998. The investigations at Brookhaven will succeed a successful set of experiments completed during FY 1995, and will require approximately 150 hours of beam time each year to support the radiation health investigators funded jointly with the NCI.

During FY 1997 and FY 1998, the space human factors project will emphasize both research and technology development. The program will conduct research to document human performance responses to long-term space flight, including especially those that affect the performance of safety-critical functions. This research will attempt to understand the factors that influence space-based performance. The program's research activities will use human-machine scenarios, models, analogs, and other tools as aids in defining human habitability requirements for space flight and in developing design and performance requirements for equipment, procedures, operations and environments in space and on the ground. The project will support the development of new designs, technologies, and systems

needed for space and ground-based operations with particular emphasis on advanced displays and controls, human-machine function allocation, interactions among intelligent agents, and intravehicular activity and extravehicular activity.

The primary emphasis of the advanced life support project during FY 1997 and FY 1998 will be on technology areas that have clear and compelling relevance to NASA during the ISS era and that will enable the Human Exploration and Development of Space. The project will demonstrate the feasibility of using higher plants to provide air, water, and food for planetary surface life support systems, demonstrate the maturity of physical/chemical recycling processes for providing air and water for planetary life support systems and complete the evaluation of continuous cropping of potato and wheat, including the recycling of nutrients from inedible plant biomass through aerobic bioreactors.

During FY 1996, JSC completed Phases I and II of the 'Early Human Test Initiative,' a month-long test of four volunteer test subjects in a closed-chamber demonstration of physical-chemical life support system technologies. During FY 1997, NASA expects to conduct an additional 60-day ground-based demonstration of regenerative life support systems with four test subjects in a closed chamber, also at JSC. At KSC, during FY 1996, a study was completed on the long-term growth of potatoes as a potential food crop for life support systems for planetary exploration and development. Of particular note was a study on recycling plant biomass to supply the nutrients required for plant growth.

To support the advanced life support project's primary emphasis on large-scale bioregenerative validation and testing, the Research and Analysis program budget request includes $2.0 million in FY 1998 to support the conversion of the Weightless Environment Training Facility (WETF) at JSC for the proposed Bio-Regenerative Planetary Life Support Systems Test Complex (Bio-Plex) in the rotunda and east service wings of the WETF. Functions previously carried out in the current WETF are being relocated to the new Sonny Carter Training Facility, leaving most of the rotunda and east service wings of Building 29 at JSC unoccupied. A facilities study performed at JSC documented that facility modifications necessary to install the new Bio-Plex in the rotunda and east service wing rather that at the site of the existing Human-Rated Test Facility would yield construction cost savings of $1.8 million.

During FY 1996, the advanced EVA systems project was restructured in an effort to revalidate its programmatic objectives. This included integrating all advanced EVA elements in the agency and transferring program management to JSC. FY 1997 resources will support proposals in the following areas: mission requirements definition; EVA human factors; physiological and medical requirements; EVA task requirements; systems studies; and EVA mission operations. Activities in this project area, pending the outcome of revalidation activities, will support such initiatives as the development of next generation EVA systems technologies.

The primary emphasis of the advanced technology development (ATD) project during FY 1997 will be on environmental sensors and biosensors. The ATD project will concentrate in particular on developing new technologies for air and water monitoring and microbial detection, as well as refining and micro-miniaturizing currently available sensors. The program will also support the development of advanced implantable biotelemetry systems.

During FY 1997 and FY 1998, the data analysis project will maintain its primary emphasis on extended data analysis and on enabling the research community's access to data. Secondary emphasis will be on the area of special data analysis techniques. NASA and NIH collaborations have yielded particularly fruitful results in Life Sciences' data analysis program, and the program will seek to build upon these past successes. SPACELINE bibliographic database capabilities will expand during the budget period, owing to the continued support provided by the National Library of Medicine. Enhancements will be made to the Life Sciences flight data archive, introduced during FY 1996, and additional database products will be developed in FY 1997 and FY 1998 for the benefit of the research community during the era of the ISS.

During the past year, Life Sciences successfully recompeted NSCORTs in gravitational biology, bioregenerative life support, and environmental health. North Carolina State University in Raleigh received a new NSCORT award for gravitational biology, and an additional gravitational biology NSCORT was established at Rice University. Wake Forest University will be a collaborating partner in the North Carolina State University NSCORT, while the JSC will be a collaborating partner with the new Rice University NSCORT. Rutgers University received an NSCORT for bioregenerative life support, and the Stevens Institute of Technology in Hoboken, New Jersey will be a collaborating partner. The new NSCORTs have received five year awards that were initiated during the first half of FY 1996. During FY 1997 Life Sciences expects to award an additional NSCORT for radiation health. Site visits and selection for the proposed radiation health NSCORT will take place during the first and second quarters of FY 1997.

During FY 1996, NASA and the NCI continued their co-sponsorship of applied research and development projects designed to lead to new breast cancer digital imaging techniques. Deriving from a long-standing agreement between NASA and the NCI, innovative breast cancer imaging techniques that were recently selected from a NASA/NCI competitive solicitation are expected to lead to highly effective, low-cost diagnostic technologies. This collaborative venture will continue in FY 1997 and FY 1998. The payoff from this effort might be huge. Recent statistics show that 186,000 new cases of breast cancer were diagnosed in the U.S. alone in 1993. Health care costs associated with breast cancer in the U.S. exceed $8 billion annually.

An active Research and Analysis-based outreach project is planned for FY 1997 and FY 1998, including outreach activities designed to attract Native Americans to careers in the space life

sciences and related engineering disciplines. Outreach programs for Native Americans attempt to develop the telecommunications information infrastructure of Tribal educational organizations. Life Sciences initiated a Native American Earth and Space Academy (NAESA) during FY 1996, and began work on providing Internet connectivity to the Navajo Community College and the Headquarters of the Cherokee Nation of Oklahoma's Sequoyah High School. Finally, Native American outreach programs will team with the Air Force Office of Scientific Research to support the Navajo Community College Telecommunications Infrastructure Development program during FY 1997, along with the planning for the All Indian Nations Forum on Telecommunications.

The Research and Analysis program will continue to encourage extramural investigators to take advantage of NASA-unique facilities to support research objectives. The program will use FY 1997 and FY 1998 budgetary resources to increase extramural access to the Biocomputation Center, the Vestibular Research Facility and other radial acceleration facilities at the ARC, along with the KC-135 flight program and other biomedical facilities at the JSC.

LIFE SCIENCES FLIGHT PROGRAM

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
Life sciences flight experiments program	54,400	39,400	35,500

PROGRAM GOALS

The Life Sciences Flight Experiments program systematically manages and supports investigations with living systems that require access to the unique characteristics of low-Earth orbit. The program secures timely space flight opportunities for the space investigations it sponsors. The science supported by the program uses microgravity and the other characteristics of the space environment to enhance understanding of fundamental biological processes. In addition, the program's flight research and technology development work provides the scientific and technological foundations for a safe, productive human presence in space for extended periods.

STRATEGY FOR ACHIEVING GOALS

The Life Sciences Flight Experiments program strives to select and develop the highest-quality research and technology. The program solicits a steady stream of new research and technology investigations, manages and supports them during pre-flight definition, development, and through post-flight activities. The program relies upon peer reviews to determine which science research and technology to endorse. Its peer review process in recent years has become

a cooperative enterprise with the National Institutes of Health (NIH). Cooperative enterprises such as those with the NIH and other external partners ensure that flight opportunities are provided to the highest-ranked, peer-reviewed research and technology projects.

The Life Sciences Flight Experiments program provides a balanced and robust series of flight opportunities which include human-assisted or human-subject flight opportunities aboard the Space Shuttle as well as research opportunities aboard unmanned vehicles. The program uses Spacelabs that fly in the Space Shuttle cargo bay as well as the Space Shuttle middeck for small payloads. As the nation approaches the era of the ISS, the Life Sciences Flight Experiments program is taking advantage of longer-duration flight opportunities aboard the Mir space station. The NASA/Mir Research program (NMRP) investigations will enable the Life Sciences Flight Experiments program to conduct research, develop technologies, and help mitigate the risks of long-duration space flight. In the ISS era, crews will remain on orbit for as long as 180 days at a time; the Life Sciences Flight Experiments program will provide enabling technologies to take maximum advantage of this long-duration opportunity.

The Life Sciences Flight Experiments program develops and supports investigations in the areas of biology, physiology, environmental health, and behavior and performance for Spacelab flight opportunities. The program's budgetary resources enable necessary pre-flight planning, development, and support for selected investigations. Program resources provide for post-flight services and appropriate data analysis and distribution, including the development of specialized databases and archiving services to ensure that flight research findings and results are widely available to the research community.

In FY 1996, Life Sciences participated in the Life and Microgravity Spacelab (LMS) mission. The last scheduled life sciences Spacelab flight is Neurolab, scheduled for the second quarter of FY 1998. The Neurolab mission will conduct basic research in sensory-motor, vestibular function, spatial orientation, developmental biology, nervous system plasticity, autonomic nervous system control of the cardiovascular system, sleep and circadian rhythms, and human behavior.

The Life Sciences Flight Experiments program also relies upon Space Shuttle small payload opportunities to supplement flight opportunities that Spacelab provides. The objectives of small payload flights are to provide scientists and researchers with opportunities to fly their research quickly and economically, via the Space Shuttle middeck. The science conducted may be in plant biology, space physiology and countermeasures, developmental biology, cellular research, human factors, and performance disciplines. Most of the research uses existing flight hardware. Small payload opportunities demonstrate hardware performance or develop research techniques for the Spacelab, the NMRP, and the Space Station. NASA anticipates that, once the Space Station becomes operational, small payload-class investigations will migrate to the Space Station's EXPRESS rack program.

In cooperation with the Russian Space Agency (RSA) the Life Sciences Flight Experiments program conducts biological experiments with non-human primates on unmanned biosatellites. The Bion spacecraft series of biosatellites flies biological and radiation measurement experiments in near-Earth orbit. Since 1973 the Russian Federation (formerly the U.S.S.R.) has launched eleven biosatellites; the U.S. has participated in the last nine missions and is scheduled to participate in the upcoming Bion 12 mission. The major objectives of the Bion investigations are to study the biological effects of microgravity and radiation on living systems; to evaluate living systems' adaptation to microgravity and other characteristics of space; and to evaluate the fundamental characteristics of living systems, using gravity as a variable. Bion missions with primates last up to fourteen days.

Contractor and Center Support

The participating Field Centers in life sciences' flight research activities and programs include the Johnson Space Center (JSC), which leads the development and support of life sciences investigations in the areas of space physiology, environmental and human factors, and advanced life support. The Ames Research Center (ARC) leads the development of space biology research investigations and plays the primary life sciences role in the development of primate investigations scheduled for launch aboard biosatellite missions. Both of these NASA Centers participate in Spacelab flights, small payloads, NMRP, and the Space Station. The Kennedy Space Center (KSC) manages life sciences payload integration, provides pre- and post-flight support, manages advanced life support facilities and demonstrations, and manages small payload investigations, especially those using plants.

International & Domestic Cooperation

The Life Sciences Flight Experiments program seeks opportunities to enhance its science research and technology development activities by promoting cooperative activities with researchers and research organizations. Life Sciences' collaborative activities with non-NASA entities include foreign partners participating in the ISS program, as part of the effort to build and enhance working relationships in preparation for the Space Station era. NASA and the ESA, for example, will both fly investigations on the ESA-built Biorack during the NMRP. On the LMS mission, the new Department of Defense-built cell culturing system was flown. On the same flight, the Torque Velocity Dynamometer developed by ESA was flown for the first time to conduct musculoskeletal and combined musculoskeletal and neurophysiological experiments. On the Neurolab mission, 10 of 32 investigators selected for development are international; investigators from Germany, Japan, Italy, France, and the Netherlands are participating. ESA (Europe), NASDA (Japan), CNES (France), DARA (Germany), and CSA (Canada) are developing Neurolab flight hardware. Domestic Neurolab participation will come from NIH, which is playing a leading role in Neurolab science management and development, the National Science Foundation, and the Office of Naval Research.

International and domestic partners also play vital roles in the Life Sciences Flight Experiments program's small payloads program. The French, Russian, German, Ukrainian, and Canadian Space Agencies represent about 25% of the annual small payloads investigator population. The small payloads program uses flight hardware provided by other federal agencies, such as the Walter Reed Army Institute for Research, along with hardware from Canada and Germany.

MEASURES OF PERFORMANCE

	FY 1996 Plan	FY 1996 Actual	FY 1997 Plan	FY 1997 Revised	FY 1998 Plan
Number of Flight Principal Investigators	148	167	134	164	138
Number of Investigators Flown	63	63	43	62	60

Performance Milestone	Plan	Actual/Revised	Description/Status
The LMS Spacelab mission flew on STS-78	3rd Qtr FY 1996	3rd Qtr FY 1996	The LMS flight supported the non-Rhesus science that had been scheduled to fly on the SLS-3 mission. The mission supported musculoskeletal and behavior and performance investigations to build on the research results of the successful SLS-1 and SLS-2 missions.
The Neurolab mission will fly on STS-90	2nd Qtr FY 1998	--	The Neurolab science payload focuses on the effects of weightlessness and other aspects of the space environment on developmental and cellular neurobiology, vestibular function, spatial orientation and visuo-motor performance, autonomic nervous system regulation, sleep and circadian rhythms, and learning and behavior.
The U.S. will share 50% of the science from the Bion 11 and Bion 12 mission	--	--	Bion 11 and Bion 12 will accommodate the Rhesus investigations that had been scheduled to fly on SLS-3. The Bion 11 and Bion 12 investigators will conduct musculoskeletal, neurosensory, immunology and regulatory physiology investigations
Bion 11	1st Qtr FY 1997	1st Qtr FY 1997	--
Bion 12	1st Qtr FY 1999	--	--

data from the ground-based science study performed the previous year and with certain experiments on Bion 11.

The LMS mission is also noteworthy for the range of collaborative arrangements that improved science and minimized costs. ESA's Torque Velocity Dynamometer, ESA's Hand-Grip Dynamometer, the Canadian Space Agency's Torso Rotational Experiment, and the French Space Agency's Canal and Otolith Interaction Studies flew on the LMS mission. The crew of the LMS mission included two international payload specialists, one from Canada and one from France. Their backups were from Italy and Spain. Remote payload operations successfully tested concepts that Life Sciences expects to apply on the ISS.

The Life Sciences Flight Experiments program continued Neurolab science planning and mission development activities during FY 1996, and the program continues on target for an FY 1998 flight aboard STS-90. The Neurolab mission is a key collaborative venture between NASA and other domestic Federal science agencies during the "Decade of the Brain." The NIH, the NSF, and the Office of Naval Research are providing funding to seventeen of the twenty-two domestic investigations that Life Sciences is now supporting for Neurolab flight development. A total of thirty-two investigations have been selected for Neurolab development, ten of which are being funded by NASA's international partners.

The Neurolab science payload focuses on the effects of weightlessness and other aspects of the space environment on developmental and cellular neurobiology, vestibular function, spatial orientation and visuo-motor performance, autonomic nervous system regulation, sleep and circadian rhythms, and learning and behavior. Human studies of the crew and animal studies of species housed in specialized facilities will be carried out. Six of Neurolab's thirty-two Life Sciences investigations do not require the full laboratory resources of a Spacelab flight and will instead be carried out as small payload experiments.

Four Neurolab payload specialist candidates were selected from twenty-five nominees and began their training during FY 1996. Two of these will be selected as payload specialists during FY 1997 and the other two will serve as alternates. Two mission specialists were assigned to the crew during FY 1996 and began training. During FY 1996, ARC and JSC carried out critical design reviews and ground-based flight simulation control studies. Final selection of Neurolab flight experiments will occur during FY 1997, one year prior to flight. Integrated design reviews of experimental hardware for the final stages of hardware development prior to integration and flight will take place during FY 1997.

During FY 1996, the Life Sciences Flight Experiments program flew eleven small payload investigations in musculoskeletal physiology, plant biology, and developmental biology. The NIH/Cells series of investigations continued during FY 1996 with the flights of NIH/Cells-5 and NIH/Cells-7. The program also participated in the NIH/Rodent-3 mission, which was a verification flight for Neurolab. The Aquatic Research Facility, belonging to the Canadian

Space Agency, was flown in addition to two plant biology experiments, for a total of six FY 1996 small payload middeck opportunities. FY 1997 and 1998 resources will continue to provide for an active life sciences small payloads program. FY 1997 resources will support the continuation of the NIH/Cells and NIH/Rodent series of investigations (using rodents, cells, and plants) along with additional life sciences small payload investigations and data analysis, for a total of six FY 1997 small payloads investigations. FY 1998 will begin with the Collaborative Ukrainian Experiment (CUE), which is a plant payload. CUE involves five U.S. Principal Investigators and seven Ukrainian Principal Investigators sponsored by the National Space Agency of Ukraine. A Ukrainian Payload Specialist has been selected to perform all in-flight operations.

Bion Program

FY 1997 resources are providing for completion of the development, testing, and delivery of flight hardware to Russia in support of the December 1996 launch of the Bion 11 biosatellite mission. The mission has flown some of the primate experiments from the canceled SLS-3 Spacelab mission. It is designed to expand our understanding and knowledge of a variety of biomedical problems in humans. It will be used to investigate the effects of weightlessness on bone, muscle, and neuromuscular structure and function, sensory-motor function, behavior, circadian rhythms, fluid and electrolyte balance, and immunology. In January 1996, the Life Sciences program exercised the option to fly the Bion 12, a mission identical to Bion 11, which will fly during the first quarter of FY 1999, thereby completing the SLS-3 primate studies.

MICROGRAVITY RESEARCH AND ANALYSIS

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
Microgravity research and analysis	30,200	31,900	36,500

PROGRAM GOALS

The Microgravity Research and Analysis (R&A) program seeks to understand basic physical phenomena and processes, quantify effects and overcome limitations imposed by gravity on the observation and evaluation of selected phenomena and processes; develop technologies related to the requirements of the research; and expand, centralize and disseminate the research data base as widely as possible to the U.S. research and technology community. The primary goal of the R&A program is to mature the research of a large number of laboratory scientists into coherent groups of flight experiments for the Space Station and research other opportunities. The R&A program is designed to establish the intellectual underpinning of the

flight program. In order to do this, a multi-disciplined research program has been established in the areas of biotechnology, combustion science, fluid physics and transport phenomena, fundamental physics, and materials science. Ground-based experiments, coupled with experiments selected for flight definition, comprise a compelling and coherent strategy for utilization of the space environment.

STRATEGY FOR ACHIEVING GOALS

The Microgravity Science and Applications mission to develop and utilize the scientific potential of space, ground-based research serves two purposes: to find and refine concepts for space experiments, and to create a framework of knowledge and expertise in which the full scientific value of space experiments can be realized. The R&A program, through its support of ground-based research, provides the genesis from which strong, well-defined flight experiments emerge. The strategy NASA has devised for achieving excellence in microgravity research is to utilize the nation's academic and industrial resources, joining prominent researchers with NASA expertise in multidisciplinary microgravity experimentation. The mechanism to engage national scientific resources is the release of NASA Research Announcements (NRAs), solicitations directed to research disciplines, inviting proposals for research and flight experiment concepts. Proposals are selected by peer panels of technical experts on the basis of scientific and technical merit and need for the microgravity environment. By soliciting for research across a discipline, rather than for specific missions, NASA allows easier entry into the microgravity program for researchers with strong merits but limited experience with the space program. Approximately 80% of the R&A budget funds research grants and contracts which are awarded through competitive peer review, with over 90% of this funding going to external investigators across the United States. The remaining 10% is used at NASA field centers to provide supporting infrastructure. NASA set out at the beginning of the 1990's with the goal of building a research program that seeks to exploit the microgravity environment possible through space flight, engaging the talent and energy of the nation's scientists and engineers to develop the potential of space for research in physical, chemical, and biological processes. Having established a strong foundation for this effort through a series of highly-successful research solicitations, NASA is working with the science and engineering community to define and build a dynamic, coherent research program. Since the inception of the R&A program in 1989, 14 NRA's covering five disciplines have been released, and over 2500 proposals have been received. Approximately 300 Principal Investigators are now in the peer-reviewed Research and Analysis ground-based program.

The five science disciplines which comprise the Microgravity R&A program are biotechnology, combustion science, fluid physics and transport phenomena, fundamental physics, and materials science.

The biotechnology project focuses on protein crystal growth, cell sciences, and fundamentals of biotechnology as areas which offer promising opportunities for significant advancements

through low-gravity experiments. Experiments in space have demonstrated that gravity influences protein crystal growth and that reduced gravity can result in improved crystal characteristics. Improved data from protein crystals will allow scientists to better understand protein structures, a critical element of structural biology and rational drug development. Cell science technology explores the cellular response to low stress environments in a technology central to contemporary biomedical research. Growing normal and cancerous mammalian tissues is a technology with enormous medical benefits and applications. Fundamentals of biotechnology is an area of exploratory research in new directions such as transport of material across membranes. Information from this research may be significant in improving the efficiency of rational drug design.

The combustion science project focuses on combustion, which is responsible for producing 85% of the world's energy as well as a significant fraction of atmospheric pollution. Pollution is a continuing hazard to life and property on Earth and in space. Combustion reactions release heat. Under gravity's influence, heat release during combustion causes a convective flow as the heated gas rises. By reducing this flow in a low gravity environment, important problems such as soot formation in flames, the spreading of fires, the burning of hydrocarbons and limits of flammability can be studied in very fundamental ways. The applications of this research to fire safety and control are becoming significant.

The fluid physics and transport phenomena project studies the properties and motions of liquids and gases, providing a conceptual framework in which to understand the role of gravity in physical and chemical processes. The program also provides a foundation for advances in technologies required for exploration and development of space, such as regenerative life support systems, utilization of local resources, propulsion systems, power generation, cryogenic and fluid management. Scientists study how fluids flow under different conditions, how energy affects fluid flows, and many other important scientific and practical issues. Investigators seek the ability to make accurate predictions of how heat and mass are transported in mixtures of fluids and vapor, with profound implications for production and control processes on Earth and in future space engineering applications.

The fundamental physics project includes the study of critical phenomena, low-temperature physics and other phenomena for which the space environment can make possible measurement of physical constants with levels of accuracy that challenge the contemporary theories in physics. Reduction and control of the forces due to gravity allow investigations to probe into the depths of physical variables to levels that allow the verification of universal theories which can then be used in a great many fields of physics with much greater confidence. This part of the microgravity program addresses science and technology issues on the forefront of physics research and includes research topics at the frontier of our knowledge.

The materials science project examines the relationship between processing, structure and properties, and strives to acquire the basic knowledge required to develop new generations of

high performance materials in areas including electronic and photonic materials, glasses and ceramics, metals and alloys, and polymers and nonlinear optical materials. Materials can be divided into crystalline (a certain long range order on the atomic scale) and non-crystalline or amorphous (no long range order). The properties of a material are largely determined by the structure of the material, and are greatly influenced by the process used in forming the material. Gravity-driven phenomena can play a huge role in this triangle of properties/processing/structure. Utilization of the low gravity environment to give insight into materials and materials processing may result in improvements to production methods and materials on Earth. The materials science research program provides the baseline for comparison with future microgravity research and identifies the deficiencies in our knowledge of materials behavior on Earth.

Collaborative Activities

Through collaboration with domestic and international science communities, the R&A program has sought to obtain concrete as well as synergistic investments by other participants. NASA has joined with the National Institutes of Health (NIH) to obtain laboratory space, diagnostic equipment, and skilled researchers to accelerate the transfer of NASA-developed bioreactor technologies to the broader science community. Through joint cooperative agreements with private industry, NASA has acquired market-valued protein derivatives and diagnostic equipment which support both industrial and government sponsored research in areas of protein crystal growth. Letters of agreement with Japan and Canada have improved the research facilities available to United States ground-based principal investigators. The Japanese have made their highly sophisticated 10-second drop tower facilities available to a broad range of United States combustion science investigators. This facility extends the capability of the 5-second drop tube in the U.S. The Canadian Space Agency has developed and offered to the United States a large vibration isolation mount that can be used in United States parabolic aircraft to provide an improved lower gravity environment on the aircraft which is an integral part of the ground-based research program.

Center and Contractor Support

Consistent with NASA's field Center mission assignments, Marshall Space Flight Center (MSFC) is the Microgravity Research Program lead center and also a center of excellence for the materials science and biotechnology portions of the program. The Johnson Space Center (JSC) contributes to the biotechnology research program by conducting research in the cell culturing area. The Lewis Research Center (LeRC) is the center of excellence for combustion science and fluid physics and transport phenomena disciplines. The Jet Propulsion Laboratory (JPL) is a center of excellence and is responsible for the fundamental physics portion of the program. Contractors are utilized for science support at the Centers and are responsible for understanding and monitoring certain investigators' science. They also assist the external scientists in the utilization of unique facilities at the centers required to carry out some of the

low gravity experimentation.

MEASURES OF PERFORMANCE

	FY 1996 Plan	FY 1996 Actual	FY 1997 Plan	FY 1997 Revised	FY 1998 Plan
Number of Ground-Based Principal Investigators	260	261	290	290	300
Number of Co-Investigators supported (Ground-Based and Flight)	300	259	330	330	340
Number of Graduate Students supported (Ground-Based and Flight)	540	544	600	600	615
Number of Refereed Publications (Ground-Based and Flight)	1200	1216	1320	1320	1360

Performance Milestone	Plan	Actual/Revised	Description/Status
Completed 134 peer-reviewed studies in the disciplines of Biotechnology, Fluid Physics and Transport Phenomena, Materials Sciences and Advanced Technology in FY 1996	--	--	A summary assessment of the results of these studies, which focus on macromolecular crystal growth as well as cellular response to low stress environments, will be included in the Annual Program Task and Bibliography of the NASA Technical Memorandum for FY 1996.
Complete 31 peer-reviewed studies in Combustion Science	September 1997	--	A summary assessment of the results of these studies, which focus on processes of ignition, propagation and extinction during combustion in a low gravity environment, will be included in the Annual Program Task and Bibliography NASA Technical Memorandum for FY 1997.
Complete 17 peer-reviewed studies in Combustion Science	September 1999	--	A summary assessment of the results of these studies, which focus on processes of ignition, propagation, and extinction during combustion in a low-gravity environment, will be included in the Annual Program Task and Bibliography NASA Technical Memorandum for FY 1999.

have been received and are undergoing peer-review for a selection of approximately 30 new awards in April 1997. The Biotechnology NRA will provide a definitive opportunity for experiments in protein crystal growth and tissue culturing, as well as a broadening of the field into fundamental studies of other areas of biotechnology. Several of these research tasks are cooperative efforts with the National Institutes of Health (NIH).

Research into new technologies for x-ray diagnostics of protein crystals has resulted in the development of a new brilliant x-ray system. This new system is capable of producing a focused x-ray beam that is more than 50 times brighter than conventional beams at a fraction of the power consumption. This new technology is so promising that a proposal has been submitted to expand the development to make the system available to ground-based laboratories throughout the research community. This new proposal is a venture including NASA, industry, academia, and the NIH.

An agreement was signed between NASA and NIH for the use of a laser light scattering diagnostic instrument in the Microgravity Fluid Physics Program. NIH, via its National Eye Institute, will use the probe for early detection and diagnosis of eye diseases such as cataracts, diabetic retinopathy, and the inflammatory diseases of the anterior chamber of the eye.

NASA made awards to 17 academic, industrial, and governmental institutions for microgravity combustion science investigations. The awards range from basic scientific research, to the development of advanced instrumentation that will be of use not only to the microgravity research community but to terrestrial research and applications as well. New topical areas include the study of flame-synthesized fullerenes in microgravity (the material for which the Nobel Prize in Chemistry was recently awarded) and metals combustion in microgravity. These will be conducted for the next four years, with extensive utilization of NASA's drop towers and low-gravity aircraft in order to perform microgravity experimentation.

A patent was awarded to researchers at Lawrence Berkeley National Laboratory, under contract to NASA Lewis Research Center for the performance of microgravity combustion science research, for their new method to lower pollutant emissions in natural-gas appliances such as residential heating furnaces and hot water heaters. Burners with their "Ring Flame Stabilizer" reduce significantly the emissions of NO_X (oxides of nitrogen) that are major contributors to smog and atmospheric contamination. The title of the patent is "Apparatus and Method for Burning a Lean Pre-mixed Fuel/Air Mixture with Low NOx Emission."

Collaborative research between Japan/NEDO and the United States/NASA was established and conducted successfully in the Japanese 10-second drop tower and NASA Lewis Research Center's 2.2-second and 5-second drop towers for investigations of fuel droplets and solid fuel burning. This collaborative research saved substantial resources for each country, by avoiding

duplicative construction of hardware, while gaining new scientific knowledge of these phenomena.

NASA awarded 33 investigations in the discipline of microgravity fluid physics and transport phenomena. The selections from the 1994 Fluids NRA represented a 50% increase in the number of ground-based research tasks supported in this program and has introduced new areas of research into the discipline, specifically in the areas of complex fluids, granular flows, and bio-fluids. With the addition of the new investigators, these areas of the broad fluid physics discipline are now approaching a critical mass. All of the areas in the fluid physics discipline are well aligned with the HEDS enterprise, yielding a fundamental understanding of physical and chemical transport phenomena that are important in the development of space.

NASA awarded 23 investigations in the discipline of fundamental physics. The addition of four investigations of laser-cooled atoms into the fundamental physics program increases the range of basic topics to be studied. These include phenomena occurring in Bose-Einstein condensates and tests of the Standard Model of physics using precise measurements made possible by the very cold temperatures (within 10^{-9} degree of absolute zero) of the atomic sample. The growing community of investigators and the maturity of their investigations has led to increases in the number of publications produced, and should also lead to a larger number of proposals for flight experiments in the December 1996 NASA Research Announcement for this discipline.

NASA made awards to 51 microgravity materials science research and analysis investigations. The awards range from basic and applied scientific research to the development of advanced data acquisition and thermophysical condition-generation technology. This selection broadened the established field of microgravity materials science research and analysis, with emphasis on studies of fundamental scientific phenomena and specific classes of materials such as polymers. The awardees will conduct research each year through FY 2000.

In FY 1997 a road map for the Microgravity Research Program, with strategies to accomplish program objectives will be prepared. This road map is analogous to those developed for NASA and the HEDS Enterprise. In addition, road maps for each of the microgravity research sub-disciplines (biotechnology, combustion science, fluid physics and transport phenomena, fundamental physics, and materials science) will be prepared. The development of these road maps will insure that the Microgravity Research Program is fully aligned with the HEDS and NASA strategic goals. These road maps are the basis for developing the discipline program contents. For each of the three time periods shown in the plan, major activities/milestones will be identified and will define the program content required to meet the stated strategic goal or objective. Subsequently this information will be used in developing the long term Microgravity Program budget requests.

The principal objective for the R&A program in FY 1997 will be to integrate the investigations selected through the three solicitations released in FY 1997 into the ongoing efforts of the microgravity program. NASA will be working with large numbers of external researchers to define flight experiments with high scientific merit, and with advisory groups as well as the community at large to achieve the focus and coherence required of a strong, productive flight program. A productive research program also requires dynamic flexibility to keep pace with the progress of scientific and technological knowledge, and in FY 1997 NASA will continue to stimulate new concepts for microgravity research through its plan for discipline conferences.

Proposals to renew promising continuing research activities, as well as new and innovative research proposals, will be selected by peer review. Proposals selected by peer-review will be judged to be in the ground-based research or flight-definition part of the program, based upon the maturity of their laboratory research and their understanding of the role of the microgravity environment.

Selection of approximately 30 biotechnology proposals for funding is expected in early 1997. NRAs for Fluid Physics and Transport Phenomena, Fundamental Physics and Materials Science will be released in FY 1997.

NASA plans to continue to increase the number of Microgravity ground-based Principal Investigators in FY 1997. The number of research proposals received is expected to exceed 600 in FY 1997, based upon past submissions and the increasing interest in NASA's microgravity research program. A large portion off these proposals will be from new investigators who believe that the microgravity environment will contribute to their research understanding. Other proposals will be from scientists who have been supported by NASA to perform laboratory research, and whose work is sufficiently mature to be included in the flight definition program.

NASA will be improving its field Center resources in FY 1997 and FY 1998, bringing new and refurbished facilities on line. This activity will strengthen the ability of NASA field Centers to support increasing numbers of investigators interested in conducting microgravity experiments. Approximately 10% of the peer-approved proposals have NASA scientists as Principal Investigators (Pis) or Co-Investigators. These civil service scientists contribute facilities and resources to assist other PIs in accomplishing their research, especially in the flight program.

MICROGRAVITY FLIGHT PROGRAM

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
Microgravity flight experiments program	76,300	73,400	64,900

PROGRAM GOALS

The primary goal of the Microgravity flight program is to advance fundamental scientific knowledge in physical, chemical, and biological processes and to enhance the quality of life on Earth by conducting scientific experiments in the low-gravity environment of space. The results derived from experiments conducted aboard suborbital rockets, the Space Shuttle, the Russian Mir Space Station, and the International Space Station (ISS) will spark the imagination of the growing academic and industrial science community, enhance the nation's technological and industrial base, and foster international cooperation.

STRATEGY FOR ACHIEVING GOALS

Over the last decade, NASA has established an active scientific program in microgravity research utilizing the Space Shuttle as a research tool. As the program moves toward the next century, the focus will shift from use of the Space Shuttle toward use of the ISS. The strategy for accomplishing the transition from the Shuttle to the ISS is to use the Mir Space Station to mitigate risk in scientific, technological, logistical, and operational planning. Today, the microgravity research program is utilizing both the Space Shuttle and the Mir to achieve its objective of providing flight experiment opportunities for investigators who can benefit from conducting experiments in the low-gravity environment of Earth orbit. Microgravity investigations are conducted in the science disciplines of biotechnology, combustion science, fluid physics and transport phenomena, fundamental physics, and materials science. The flight program provides scientific apparatus (e.g., flight hardware) for experiments for a wide range of flight opportunities in the Space Shuttle middeck, Space Shuttle cargo-bay, Spacelab, Spacehab, the Mir, and the ISS. Experiment apparatus ranges from small hand-held single experiments to multi-rack, facility-class hardware which can accommodate multiple investigators. The program includes selection, definition, development, in-flight operational support, and data analysis/archiving for all microgravity flight experiments. The flight program, in conjunction with the NASA/Mir Research program and the Space Station Research program, comprise the activities necessary to accomplish the Microgravity research flight program in the 21st century.

The flight experiments program meets peer-reviewed science requirements through the development of appropriate infrastructure, experiment apparatus, flight opportunities, and advanced technologies. The flight experiments program develops experiments, supports science operations, and analyzes flight data and samples in all the major Microgravity

organizations to combine the research goals of those organizations to generate results from flight experiments which have previously eluded researchers on earth.

NASA is utilizing the ubiquitous presence and capability of the Internet and the World Wide Web (WWW) to generate real-time displays of the microgravity environment. By utilizing the WWW, NASA is able to provide global access to the Shuttle microgravity environment data to all researchers.

Center and Contractor Support

NASA's FY 1995 Zero Base Review (ZBR) assigned the Agency mission of microgravity to the Marshall Space Flight Center (MSFC). In response to the recommendations of the ZBR, the NASA Headquarters Office of Life and Microgravity Science and Applications (LMSA) and MSFC established the Microgravity Research Program Office (MRPO) at MSFC to provide integrated program planning and management of NASA's Microgravity development program. In addition to its lead center assignment, MSFC is responsible for the execution and project management of the microgravity biotechnology, materials science and glovebox flight programs. Science support at MSFC is provided by the Universities Space Research Association through its member universities and the Alliance for Microgravity Materials Science (AMMSA). Engineering support is provided by various hardware contractors. Under the leadership of the MRPO, JSC executes the cell sciences portion of the biotechnology program with contractor support from Krug Life Science Corporation. LeRC executes the combustion science, fluid physics and transport phenomena, and acceleration measurement programs with contractor support from NYMA and Analex Corporations. The fundamental physics program is executed by JPL with support from Stanford University and Ball Aerospace Corporation.

International and Other Federal Agencies Support

The European Space Agency (ESA) developed the Spacelab module that is used in the United States Microgravity Laboratory (USML), the Life and Microgravity Spacelab (LMS), and the Microgravity Science Laboratory (MSL) missions. Additionally, our international partners developed nearly all of the experiment apparatus that flew on the second International Microgravity Lab (IML-2). That apparatus was shared by both international and United States investigators.

The Spacelab glovebox that flew on USML-2 was developed by ESA and, in exchange for U.S. use of this glovebox on USML-2, NASA has twice flown two units of the ESA Advanced Protein Crystallization Facility (APCF) in the middeck of the Space Shuttle. Both U.S. and European investigators used the APCF on this quid-pro-quo agreement with ESA. In addition, an agreement is being negotiated with ESA for additional flights of the APCF. Each flight was for two APCF units with a total of 96 protein crystal growth cells where the

U.S. investigators would get 48 cells.

Research aboard the LMS mission in biotechnology, fluid physics and transport phenomena, and materials science allowed United States investigators to use instruments developed by ESA, broadening the basis for international cooperation in space research. Both United States and international investigators used the European-developed Isothermal Dendritic Growth Experiment (IDGE), Material pour l'Etude des Phenomenes Interessant la Solidification sur Terre et en Orbite (MEPHISTO), and the Advanced Gradient Heating Facility (AGHF) to conduct numerous materials science experiments.

The MSL-1 mission will conduct materials science research using the National Space Development Agency of Japan (NASDA)-developed large isothermal furnace and the German-developed Tiegelfreies Elektromagnetisches Prozessieren Unter Schwerelosigkeit (TEMPUS) hardware. Both United States and international investigators will utilize this hardware during MSL-1.

The USMP-4 mission will conduct materials science research using internationally developed hardware that flew on previous USMP missions which has been upgraded to conduct new peer-reviewed science experiments.

NASA and ESA are jointly conducting a definition study of the Satellite Test of the Equivalence Principal (STEP) experiment, which will be a candidate for an ESA mission in the 2001-2003 time frame. The Microgravity Science Payload (MSP-1) mission, scheduled for February 2001 will include a reflight of up to two MEPHISTO furnaces, with both United States and international investigators, as well as reflights of other United States materials science experiments.

The NIH has invested billions of dollars of ground-based research in cell culturing. The NASA/NIH agreement on the use of NASA's bioreactor technology allows NASA to take advantage of this significant investment and analysis base to extend the understanding of structure and functions applicable to cell culture flight experiments using the NASA-developed bioreactor.

MEASURES OF PERFORMANCE

	FY 1996 Plan	FY 1996 Actual	FY 1997 Plan	FY 1997 Revised	FY 1998 Plan
Number of Flight Principal Investigators	40	36	40	40	40
Number of Investigators Flown	23	23	23	25	6

Performance Milestone	Plan	Actual/Revised	Description/Status
USML-2 Launch	4th Qtr FY 1995	1st Qtr FY 1996	USML-2 focused on the physics of crystallization, fluid dynamics and biotechnology. Investigations continued from the highly successful USML-1 mission (6/92), as well as new investigations chosen since that time.
USMP-3 Launch	2nd Qtr FY 1996	2nd Qtr FY 1996	The USMP-3 mission focused on experiments in microgravity materials science and included reflight of the AADSF, IDGE, MEPHISTO, and Zeno. Both European and U.S. investigations were conducted.
Life and Microgravity Sciences Mission (LMS) Launch	3rd Qtr FY 1996	3rd Qtr FY 1996	The LMS mission was the first flight of the ESA Advanced Gradient Heating Furnace (AGHF), a new furnace facility available to NASA to conduct materials science investigations selected in 1992 on the physics of multiphase solidification. Several ESA investigations were also conducted. The Bubble Drop and Particle Unit also supplied by ESA supported a wide range of fluid physics investigations.
Microgravity Science Laboratory (MSL-1) Launch	Plan: 2nd Qtr FY 1997	--	The MSL-1 flight will carry major NASA-developed instruments for research in combustion science and fluid physics (Combustion Module-1 (CM-1), the Droplet Combustion Experiment (DCE) and the Physics of Hard Spheres Experiment (PHASE)). These investigations explore phenomena central to pollution control, engine efficiency, fire safety, and phase transformation. Using both German and Japanese-developed hardware and both U.S. and international investigators, materials science investigations will continue investigations which were begun on IML-2.

USMP-4 Launch	1st Qtr FY 1998	--	The USMP-4 mission will focus on experiments in microgravity materials science and will be a reflight of hardware from the USMP-3. Both European and U.S. investigations will be conducted.

ACCOMPLISHMENTS AND PLANS

The major FY 1996 efforts in the Microgravity Research Flight Experiments Program were focused on the USMP-3 Spacelab and LMS missions. USMP-3 included the same complement of experiment facilities as USMP-2: three solidification furnaces, each of which is designed to examine a different type of crystal growth, and a fluids facility. While the majority of the hardware is the same, the scientific research is new. Principal Investigators have used the data from USMP-2 to redesign experiments to probe more deeply into phenomena that yielded numerous scientific insights.

Research aboard the LMS mission in biotechnology, fluid physics, and materials science allowed U.S. investigators to use instruments developed by ESA, broadening the basis for international cooperation in space research. The LMS mission was the first to fly the ESA Advanced Gradient Heating Furnace (AGHF), a new furnace facility of significant interest to the U.S. science community available to NASA through international cooperation. The AGHF was used by NASA to conduct two materials science investigations selected in 1992 on the physics of multiphase solidification. Several ESA investigations were also conducted. The Bubble, Drop and Particle Unit (BDPU) was modified and used to conduct two new NASA investigations, as well as experiments sponsored by ESA. NASA protein crystal growth project conducted two new types of experiments on the 16-day mission.

In August 1996, the Agency decided to terminate, by July 1997, the dedicated use of the leased DC-9 based at Lewis Research Center for providing parabolic aircraft flight support to NASA's microgravity research program. As the Microgravity Lead Center, the Marshall Space Flight Center (MSFC) has been directed to validate the parabolic aircraft requirements (annual flight hours needed) for all NASA-sponsored microgravity research (both Microgravity Research and Space Product Development, and to develop an implementation plan for providing parabolic support to NASA's microgravity research program. The plan, to be in place prior to termination of the DC-9 agreement, will include the details for return of the DC-9 to the lessor, and address the validation of all Agency KC-135 requirements.

Biotechnology

Principal Investigators and numerous Guest Investigators. This large number of samples provided opportunities for investigators to use multiple sample protocols and build a statistical basis for their investigations. Several samples were flown to help develop a system that will investigate the fundamental mechanisms by which protein crystals form. This knowledge will assist not only investigators growing crystals in space, but investigators performing such experiments in their Earth-bound laboratories.

The first long duration flight of a cell and tissue culturing device was placed in orbit in the Mir during FY 1996. This unit, a pathfinder for Space Station cell laboratories, has already grown three dimensional cartilage cell constructs larger than those attainable in terrestrial laboratories.

Combustion Science

NASA awarded grants to three new investigators for spaceflight experimentation in microgravity combustion science. These involve the development of testing methodology and apparatus for categorizing the flammability of spacecraft materials in microgravity, the study of multi-component fuel droplets, and the study of so-called "cool flames," applicable to internal combustion engine performance. The definition of these experiments and subsequent peer reviews for approval for spaceflight will take place over the next few years.

Flown during the USMP-3 mission in February, 1996, three combustion investigations were performed in order to begin to directly address on-orbit safety of the crew from accidental fire. The Radiative Ignition and Transition to Spread Investigation and the Forced Flow Flame Spread Test studied the transition from a momentary ignition to a fire spread situation; from a scientific perspective these were highly successful as they identified new and unpredicted behavior. The third, Comparative Soot Diagnostics, provided the first test data on the in-space performance of the Shuttle's and the ISS smoke detection systems while determining particulate sizes and concentrations from typical spacecraft materials and a selected hydrocarbon fuel.

NASA will reach a major milestone on MSL-1 in March, 1997 in combustion science in microgravity with the on-orbit performance of many combustion experiments. These include one examining soot formation and oxidation (an area of critical importance to environmental and manufacturing concerns); another examining isolated fuel droplet combustion (an area of classical textbook interest and needed for improved modeling of engines and propulsion systems); and a third examining unique premixed hydrogen-oxygen-diluent burning (an area of long-standing scientific interest and to provide baseline data for hydrogen burning behavior).

Fluid Physics and Transport Phenomena

The Critical Viscosity of Xenon (CVX) experiment will be conducted on STS-85 in July

1997. This is a fundamental physics experiment to determine the critical exponent for xenon more accurately than is possible under normal gravity. The CVX data will be used to quantitatively test the form for the crossover theory of critical viscosity and provide complementary results with the Zeno experiment to test the mode coupling theory of critical phenomena.

The Physics of Hard Spheres Experiment (PHASE), being carried aboard the March 1997 MSL-1 mission, will examine order-disorder transitions in colloidal suspensions.

The first flight of the Extensional Rheology Experiment (ERE) will be conducted on a sounding rocket in late FY 1998. The science objectives are: 1) to generate a simple, homogeneous, shear-free flow in the material, to perform the first direct measurements of the extensional viscosity of a dilute polymer solution in uniaxial stretching flow during constant strain rate deformation and to characterize how this property varies with time and deformation rate; 2) to perform measurements of transient stress growth and relaxation of the test fluid; and, 3) to successfully isolate the mechanisms associated with elastic deformation and viscous hydrodynamics.

Science requirements are being established and the design of the test section hardware has begun for the Two-Phase Extended Evaluation in Microgravity (TEEM) experiment - a joint project between NASA JSC, LeRC and GSFC. The objective of this experiment is to provide extended duration microgravity data on two-phase systems necessary for risk mitigation for the International Space Station, in support of technologies for NASA's Enterprise for the Human Exploration and Development of Space. A launch opportunity for TEEM has not yet been established.

Fundamental Physics

The Critical Fluid Light Scattering Experiment/Zeno successfully completed its second flight on the USMP-3/STS-75 mission in February 1996. Zeno was a fundamental physics Experiment to extend and improve measurements of the decay rates and the correlation length of critical fluctuations in a simple fluid very near its liquid-vapor critical point. This second flight completed the flight experiment program of the Principal Investigator. The flight data are currently being analyzed.

Materials Science

The Isothermal Dendritic Growth Experiment (IDGE) is a fundamental microgravity materials science experiment that has been flown twice as part of the United States Microgravity Payload (USMP) series on the space shuttle Columbia. The first two flights of IDGE have provided the first ever set of convection-free dendritic growth data. Because virtually all industrially important alloys solidify from a molten state by a dendritic process, a

fundamental understanding of dendritic solidification is necessary to correct mathematical models that provide the basis for improved industrial production techniques. In addition, during the February 1996 USMP-3 mission, the IDGE became the first U.S. microgravity experiment to be commanded and controlled from the Principal Investigator's university. Researchers and students from the Rensselaer Polytechnic Institute controlled the Isothermal Dendritic Growth Experiment (IDGE) through an electronic link to the NASA Lewis Research Center's Telescience Support Center. Remote telescience operations is a very cost effective tool that enables researchers to conduct microgravity experiments from their own facility, rather than traveling to a NASA operations center to conduct an experiment. This demonstration of telescience capabilities is especially important as this is the likely operations scenario for the coming International Space Station era. IDGE's third flight is scheduled for October 1997, aboard USMP-4.

The first flight of the Mechanics of Granular Materials (MGM) experiment was completed on the STS-79/Mir-4 mission in September 1996. The science objective is to obtain quantitative knowledge of the behavior of bulky granular materials under low confining pressures. The resultant data will be important in the understanding of soil mechanics and geotechnical engineering, earthquake engineering, coastal and off shore engineering, mining engineering, planetary geology, granular flow processes and engineering with granular materials. A second flight is scheduled for STS-86 in 1997 to complete the experiment data requirements matrix.

Three materials science experiments will be conducted on the MSL-1 mission in April, 1997: Coarsening in Solid-Liquid Mixtures (CSLM), Liquid Phase Sintering-2 (LPS-2), and Diffusion Processes in Molten Semiconductors (DPIMS). The objective of the CSLM is to study the coarsening kinetics of tin-rich particles in the eutectic liquids of lead-tin alloys of various compositions.

The second flight of the Bismuth-Tin Solidification Experiment (BiSn-2) on USMP-4 in October 1997 will provide data on the solidification behavior and the solid-liquid interface stability of bismuth and bismuth-tin alloys during crystal growth. It uses the Seebeck technique to measure interface undercooling temperature, resistance change across the sample to measure interfacial velocity, Peltier pulsing for demarcation of the sample interface, and quenching for chemistry and structure near the solid/liquid interface at temperature. The experiment is to be carried out in the French-developed MEPHISTO furnace.

NASA/NIH Program

The cell culture technologies and protein crystal growth research constitutes the major NASA/NIH emphasis for the next 5-6 years, but it is anticipated that other areas of cooperation will evolve from preliminary results. Over the past years, NASA has explored many aspects of the growth of protein crystals and the development of tissue culturing technologies which offer great promise. Similar types of efforts are being explored with

several other institutes. This program will stimulate the joint agreements with other Federal agencies.

Two multidisciplinary research centers are supported: Massachusetts Institute of Technology, Cambridge and the Wistar Institute, Philadelphia. These Centers expand the pace of technology transfer in the biotechnology areas begun under the NASA-NIH inter-agency agreement. Through NASA-NIH cooperation, NASA has funded approximately 28 research proposals. It has also supported NIH-approved researchers in testing of tissue samples in NASA bioreactors at JSC. This has proven to be a very important undertaking in getting researchers to test NASA technology and in gaining acceptance in the larger biomedical community.

NASA is currently working with the National Eye Institute (NEI) to transfer NASA technology. This technology involves the use of laser light scattering to detect early signs of the onset of cataract formation. Discussions with the NEI have led to the decision to proceed with development of a prototype diagnostic tool. After successful demonstration, the NEI is interested in obtaining the technology for use in a large scale clinical trial.

NASA is also collaborating with the National Eye Institute using protein crystal growth technology to determine the structures of important proteins related to the signal pathway for sight. This is a joint program between NASA, NIH, and Eli Lilly.

SPACE PRODUCT DEVELOPMENT

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
Space Product Development	26,500	13,000	12,900

PROGRAM GOALS

Beginning in FY 1997, the Space Product Development activities previously budgeted within Space Access and Technology will be transferred to Life and Microgravity Sciences and Applications. The Space Processing budget has two program elements: the Space Product Development program and the Space Station Utilization program. The goal of the Space Product Development program is to facilitate the use of space for commercial products and services. These products and services can either be produced in space, or be the result of new approaches to ground-based commercial activities using insights gained from space flight. Consistent with this goal, the Space Product Development program seeks to increase U.S. business participation and investment in space-linked commercial goods and services in order to benefit U.S. industry and the economy as a whole. The program also seeks to provide the opportunity for students to engage with industry in space program activities.

As part of the establishment of the Lead Center management for the International Space Station at the Johnson Space Center, and the dissolution of the Office of Space Access and Technology, the LMSA program now includes management responsibility for these Space Product Development activities. Funding for the commercial and technology experiments planned for the International Space Station is now included under the Space Station research program, and discussed in that budget section.

STRATEGY FOR ACHIEVING GOALS

The Space Product Development program is conducted in partnership with industry, universities, state governments and other Federal agencies. The program's purpose is to facilitate the use of space for commercial products and services. To accomplish this in-space commercial research and to develop industry partnerships, the program uses Commercial Space Centers (CSCs), specific project centers, and several NASA field Centers . The commercial centers are non-profit organizations, based at universities and NASA field Centers. The CSC's provide excellent opportunities to seek numerous and varied industrial affiliations. The Space Development program includes the following CSC's:

- Center for Bioserve Space Technologies University of Colorado at Boulder
- Center for Macromolecular Crystallography University of Alabama at Birmingham
- Consortium for Materials Development in Space University of Alabama at Huntsville
- Space Vacuum Epitaxy Center University of Houston, Texas
- Wisconsin Center for Space Automation University of Wisconsin at Madison and Robotics
- Center for Commercial Applications Colorado School of Mines, Golden, CO.for Combustion in Space
- Microgravity Automation Technology Center Environmental Research Institute of Michigan, Ann Arbor, MI
- Center for Space Power & Advanced Auburn University, Auburn, AL
- Electronics (casting research)
- Worcester Polytechnic Institute Worcester, MA
- Vanderbilt University Nashville, TN

The Space Product Development program provides the required access to NASA experiment facilities and offers access to space, utilizing the Shuttle mid-deck, SPACEHAB and Wake Shield facilities. Such access is prohibitively expensive for most corporations or small businesses, especially at the high-risk, exploratory stages. This barrier to access the commercial use of space has greatly inhibited the commercial development of space-linked products or services. Through the cost-sharing partnerships between NASA, the universities and industry offered by the Space Products Development program, private enterprises of all sizes are able to afford the research most important to the development of space-linked

commercial products and services.

The Space Product Development Program has made significant progress in facilitating the commercial uses of space. As displayed in the metrics, nearly 200 commercial partners, invested over $40M in FY 1996 to use space to enhance their competitive position, develop new products and impact their "bottom line." In the process they create jobs, and contribute to "quality-of-life" improvements. This is consistent with the frequent access-to-space opportunities in FY 1995 and 1996. The decrease in these metrics is a result of reduced space research opportunities, as the Shuttle is being increasingly focused on the assembly of the International Space Station, with early Station utilization being rephased by changing Space Station requirements. The ability to retain, much less increase, commercial interest will become a significant challenge.

MEASURES OF PERFORMANCE

The metrics for the Space Product Development area capture the number of university and industry affiliates that are working with NASA in the commercialization of space and the amount of funding leveraged from non-NASA sources by the Commercial Development Centers. The complete set of metrics also address patents, publications and commercial activity measures for Space Products.

	FY 1996	FY 1997	FY 1998
Industry Affiliates	150	50	30
University Affiliates	60	50	20
Payloads Flown	24	5	2
Non-NASA $M Leveraged	$40M	$40M	$30M

FY 1996	**Payload**	**Plan**	**Actual**
STS-75/Columbia	Commercial Protein Crystal Growth (CPCG)-09	February 1996	February 1996
STS-77/Endeavour	Spacehab-4 (10 payloads)	May 1996	May 1996
STS-79/Atlantis	Extreme Temperature Translating Furnace; Commercial Generic Bioprocessing Apparatus (CGBA) Materials in Devices as Superconductors; CPCG	August 1996	September 1996
FY 1997	**Payload**	**Plan/Revised**	**Actual**
STS-80/Columbia	Wake Shield Facility-3 (WSF-3)/ CMIX-4 (commercial expmt)	November 1996	November 1996
STS-83/Columbia	Astroculture/Plant Generic Bioprocessing Apparatus	March 1997	
STS-86/Atlantis	Liquid Phase Sintering/CGBA/CIBX (commercial experiment)	September 1997	
FY 1998	**Payload**	**Plan**	
STS-89/Endeavour	X-ray Detector Test	January 1998	

ACCOMPLISHMENTS AND PLANS

In FY 1996, four CSC payloads flew on Shuttle missions: the Commercial Generic Bioprocessing Apparatus (CGBA) on STS-79, the Korund Liquid Phase Sintering metallurgy

source to treat psoriasis will be concluded in FY 1996. Significant advances in treatment of breast melanoma and other tumors with LED technology and interactive drugs have also been achieved in FY 1996. The SPACEHAB-4 flight is expected to provide float zone single crystals of Gallium Arsenide and Gallium Antinomide for advanced electronic applications such as faster computer processing.

Conquest I launch took place April 3, 1996 as part of the Congressionally-mandated launch voucher demonstration.

In 1997 the zeolite industry will propose experiments designed to improve the catalytic value of zeolites, which in turn will increase the yield of certain petroleum products in petroleum refineries.

A multi-use, Space Station-based X-Ray diffraction facility has been defined and development will start in FY 1997. The facility will produce images of the internal structures of protein crystals grown on the Space Station, allowing rapid characterization and definition of the crystals. The capability to produce this imaging data in space and deliver that data to customers on Earth will be essential to optimize the Space Station's commercial protein crystallography operations, to provide timely data and to avoid loss of crystal degradation due to time delays.

The expanded double locker plant growth chamber will undergo key milestone reviews in FY 1997. The chamber is the product of a cooperative program between the Wisconsin Center for Space Automation and Robotics (at the University of Wisconsin in Madison) and Bioserve Space Technologies (at the University of Colorado in Boulder) and Kansas State University. It will be used for applied research exploring phenomena such as lignification of plants and gene splicing to produce superior plant stock for the agricultural industry.

Flight hardware will continue to be fabricated in FY 1997 for use in KC-135 experiments for the Solidification Design/Thermal Properties Measurement program.

The Space Product Development program plans to work with its centers and their industrial partners to capitalize on the results from initial experiments to complete planning for the commercial utilization of the Space Station. The intent is to focus resources on those applications and processes showing the greatest potential for commercial success.

Phase II clinical trials will be initiated for the Light Emitting Diode (LED) technology used for medical application to combat disease.

Cooperative research activity will be developed between the Consortium for Materials Development in Space and the commercial sector for transplantable cell tissue. If the Gas Permeable Polymer Materials (GPPM) flight results are positive, FDA clinical trials will be initiated for improved contact lenses. NASA technical analyses will be provided in support of

the Critical Design Review for the plant growth chamber/Commercial Plant Growth Biotechnology Facility. Ground-based transition of plant growth facility for terrestrial use will also be pursued as will candidate drug spin-off of IMMUNE flight research. (The primary thrust of research focuses on immune system strengthening and countering bone loss. It is anticipated that specific drug therapies will emerge and be brought into the market place through this research.)

Significant work is planned in FY 1998 at all of the CSC's. Phase III clinical trials will continue for the LED technology in medical application. This will be the product development transition year. This work will be performed at the CSC/Wisconsin Center for Automation and Robotics.

Prototype completion is planned of the Plant Growth Biotechnology Facility at the CSC/Bioserve Space Technologies and Wisconsin Center for Automation and Robotics.

Market development of products in the magnetic bacteria immunoassay project, using results from flight data (CSC/Bioserve Space Technologies flight). Substantial effort is planned in the area of Mammalian Cell Stabilization, a process to inhibit cell growth, that is a potential tool against cancer. The goal for this area for FY 1998 is commercial medical transition, based on flight results (CSC/Bioserve Space Technologies flight).

Industry, the Commercial Space Centers and NASA, will continue definition studies and commitment to future flight products. Twenty industrial commitments to the Combustion Center are targeted, using a defined path to Station utilization using as many LMSA developed facilities as practical. Space Station will be the "test bed" and technology platform for combustion activities once it is available for commercial utilization (CSC/Center for Commercial Applications of Combustion in Space).

Efforts will continue to bring to market those pharmaceuticals already engendered by previous space flight activity (CSC/Center for Macromolecular Crystallography flights).

SPACE SHUTTLE/SPACELAB MISSION MANAGEMENT AND INTEGRATION

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
Space shuttle/spacelab mission management and integration	53,600	24,200	6,900

PROGRAM GOALS

The goals of this program are twofold: (1) provide physical, analytical, and operations

integration support to achieve NASA mission objectives for the science and technology communities; and (2) ensure integrated scientific, technological, and commercial user advocacy and coordination of requirements for the next generation of space laboratories.

STRATEGY FOR ACHIEVING GOALS

In order to meet the program goals and objectives, NASA performs the mission planning, integration, and execution of all NASA Spacelab, Spacehab, the NASA/Mir Research Program (NMRP), and other attached Space Shuttle payloads to carry out a wide variety of space research. The program also supports the common small science payloads that use locker spaces in the Space Shuttle's lower crew compartment. Activities include system management and engineering development of flight support equipment and software; development of interface hardware; payload specialist training and support; integration of the science payloads with the Spacelab system; payload flight operations; and data dissemination to experimenters. Mission management activities are dependent upon the specific mix of missions in a particular year.

In addition, through this program, NASA carries out systems engineering efforts to develop and evaluate strategies and processes for satisfying current and future research mission objectives. These tasks not only address the current Space Shuttle/Spacelab mission integration processes, but, based on this knowledge base, they define and support new effective and efficient processes and tools for carrying out integrated research advocacy, requirements coordination, mission planning and operations for future space platforms. In particular, the program is investigating ways to apply the engineering and operations lessons learned in the Spacelab program and the NMRP to the ISS program to achieve greater efficiencies.

Center and Contractor Support

The principal NASA Centers which conduct activities in support of this program are the JSC, the KSC, and the MSFC. In FY 1998, JSC will provide the analytical integration and operations level project management support for the remaining two NMRP missions (NASA/Mir 8 and NASA/Mir 9, scheduled to be launched in the first and second quarters respectively), and the Neurolab mission (scheduled to be launched in the second quarter). MSFC will provide the analytical integration and operations level project management support for the United States Microgravity Payload (USMP)-4, to be launched in the first quarter. KSC will provide the physical hardware science payload integration project management support for the NASA science payloads on the Neurolab and USMP-4 flights.

In FY 1998, the primary contractors that will be supporting the program at the Centers are: Lockheed-Martin at JSC; the McDonnell Douglas Corporation's Payloads Ground Operations Contract (PGOC) at KSC; and Teledyne-Brown Engineering at MSFC. At JSC, Lockheed-Martin provides payload mission integration support for the missions managed by

the JSC. At MSFC, Teledyne-Brown provides payload mission integration support for the missions managed by MSFC. At KSC, the primary PGOC functions include: processing flight hardware experiments for Spacelab and partial payloads, manifest scheduling and work control support, logistics support and sustaining engineering modifications to facilities and systems, and computational services for the Payload Operations Computer Network.

MEASURES OF PERFORMANCE

The most significant measure of performance is the provision of an integrated system that ensures successful accomplishment of the science payload objectives. Although not directly responsible for the success of a particular experiment, the mission management organization is responsible for ensuring that all necessary planning and integration of the collected set of instruments have been comprehensively completed and fully coordinated so that the experimental hardware in concert with flight crew performance and ground control direction have the opportunity to conduct the planned science activities. Science payload objectives vary considerably depending upon the type of mission supported (module missions, pallet/MPESS missions or Space Shuttle Middecks) and the type of scientific investigations performed (microgravity, life sciences, Earth and stellar observations). Depending upon the type of payload, performance is measured in terms of the number of primary missions and the number of middeck missions successfully flown as scheduled and the successful accomplishment of the science payload objectives:

	FY 1996 Plan	FY 1996 Actual	FY 1997 Plan	FY 1997 Revised	FY 1998 Plan
Spacelab/Pallet Missions	3	3	3	3	3
Mir Missions	3	3	3	3	2
Middecks/Small Payloads	8	8	5	8	12

Performance Milestone	Plan	Actual/Revised	Description/Status

USML-2 Launch	4th Qtr FY 1995	1st Qtr FY 1996	The objectives of this Spacelab module mission were to conduct scientific and technological investigations in materials, fluids, combustion and biological processes and to explore potential applications of space for commercial products and processes. Fifteen investigations were baselined for this mission, as well as seven additional U.S. investigations conducted in the USML-2 Glovebox facility. This mission was successfully conducted in the first quarter of FY 1996, having been delayed due to Shuttle program considerations and weather problems.
USMP-3 Launch	: 2nd Qtr FY 1996	2nd Qtr FY 1996	This USMP-3 mission performed materials processing and other experiments in the microgravity space environment with in-flight monitoring of phenomena, sample production, and post-flight analysis of samples. Such activities are expected to significantly advance the basic knowledge of materials science and help develop better products and technology for use on Earth and in space. This mission was launched on schedule and was highly successful in the achievement of its scientific goals**.**
LMS Launch	: 3rd Qtr FY 1996	3rd Qtr FY 1996	The LMS module mission performed scientific investigations in the fields of materials science, fluid physics, protein crystal growth, and biotechnology. Human and plant studies and a subset of investigations previously planned for SLS-3 were also conducted. This mission was launched on schedule and was highly successful in the achievement of its scientific goals**.**

ORFEUS-SPAS 2 Launch	1st Qtr FY 1997	1st Qtr FY 1997	The second flight of the Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer Shuttle Pallet Satellite (ORFEUS-SPAS-2) is an astronomical telescope for observations at very short wavelengths in two spectral ranges, the far ultraviolet (FUV) and the extreme ultraviolet (EUV). These spectrometers are mounted on the German built deployable/retrievable ASTRO-SPAS carrier.
MSL-1 Launch	: 2nd Qtr FY 1997	--	The MSL-1 will focus on microgravity combustion and international research in microgravity materials science. Three new microgravity combustion experiments will use two new, large research facilities constructed for this mission.
CRISTA-SPAS 2 Launch	4th Qtr FY 1997	--	The second flight of the Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere Shuttle Pallet Satellite (CRISTA-SPAS-2) is a set of spectrometers which measures the constituents of Earth's middle atmosphere. These spectrometers are mounted on the German built deployable/retrievable ASTRO-SPAS carrier.
USMP-4 Launch	1st Qtr FY 1998	--	This USMP-4 mission will perform materials processing and other experiments in the microgravity space environment with inflight monitoring of phenomena, sample production, and postflight analysis of samples. Such activities are expected to significantly advance the basic knowledge of materials science and help develop better products and technology for use on Earth and in space.
Neurolab Launch	2nd Qtr FY 1998	--	This mission will perform international research in brain function and behavior, including research on the autonomic nervous function, sleep regulation, vestibular physiology, developmental neurobiology, and sensorimotor function

Alpha Magnetic Spectrometer Launch	3rd Qtr FY 1998	--	This Department of Energy (DOE) sponsored AMS payload will fly twice, first on the Space Shuttle in 1998 and later on the International Space Station. AMS will search for cosmic sources of antimatter and missing matter (Co-manifested With NASA/Mir-9).

ACCOMPLISHMENTS AND PLANS

In FY 1996, the Space Shuttle/Spacelab Mission Management and Integration program successfully managed three Shuttle missions: the second flight of the United States Microgravity Laboratory (USML-2), scheduled for flight during the last quarter of FY 1995, was delayed until the first quarter of FY 1996, due to Space Shuttle program considerations and inclement weather; the third flight of the United States Microgravity Payload (USMP-3) mission was scheduled and successfully accomplished during the second quarter; and the Life and Microgravity Sciences (LMS) mission was scheduled and successfully accomplished during the third quarter. In addition to the three Shuttle missions, the mission management organization supported the flights of 8 smaller middeck class science payloads sponsored both by NASA and other government agencies.

During FY 1997, the mission management organization will provide mission management support to the launch of the MSL-1 mission in addition to 3 flights to Mir (discussed within the Space Station program narrative.) The organization will also provide program coordination for the second flights of the Cryogenic Infrared Spectrometers and Telescopes for NASA the Atmosphere Shuttle Pallet Satellite (CRISTA-SPAS-2) and the Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer Shuttle Pallet Satellite (ORFEUS-SPAS-2) missions, both scheduled for launch in FY 1997. In FY 1997, systems engineering efforts will continue to support methodologies for advocacy and coordination of U.S. research requirements and implementation of processes and tools for mission planning for US payloads on future space platforms, primarily the phase II and III of the ISS. Space Station planning and integration efforts will intensify as the First Element Launch date of the ISS approaches (December 1997). Spacelab-related activities will be sharply reduced in FY 1997, because the Spacelab modules fly for the last time in early 1998.

During FY 1998, the mission management organization will provide mission management support to the launch of three Shuttle missions which will conduct Life and Microgravity scientific research: the fourth flight of USMP; the Neurolab mission; and the precursor flight of the Alpha Magnetic Spectrometer (co-manifested with NASA/Mir-9) along with two flights of the NMRP (NASA/Mir 8 and NASA/Mir 9). FY 1998 marks the conclusion of the very successful Spacelab program with the completion of the Neurolab mission.

AEROSPACE MEDICINE AND OCCUPATIONAL HEALTH

BASIS OF FY 1998 FUNDING REQUIREMENT (Thousands of Dollars)	FY 1996	FY 1997	FY 1998
Aerospace Medicine and occupational health	8,000	3,800	7,500

PROGRAM GOALS

The goals of the Aerospace Medicine and Occupational Health programs are to: 1) provide for the health care and well-being of all NASA employees in their ground- and space-based work environments; 2) develop appropriate requirements for medical operations and medical research; and 3) promote applications of knowledge gained and technologies developed in the public and private sectors.

STRATEGY FOR ACHIEVING GOALS

The primary objectives of the Aerospace Medicine and Occupational Health programs are to support the NASA Mission through the preservation and maintenance of the physical and mental health of Agency employees and the health and productivity of the astronauts, thus increasing the probability of success of space flight missions. The scope of work includes the refinement of standards and requirements for operational medicine in support of human space flight; provision of ground-based medical support for human space flight mission operations; and ensuring development of hardware, training, and protocols for maintaining clinical care readiness on-board spacecraft.

To achieve the program goals, several activities have been established, which are investments in technologies that will enable NASA to meet the challenges of space exploration in the new millennium. In addition, these technologies are being utilized today to enhance our abilities to provide medical care and medical education to NASA employees regardless of their location.

The Global Health Applications activity transfers NASA knowledge and technology achieved in aerospace medicine and occupational health to a variety of domestic and international endeavors that contribute to national competitiveness, education, and quality of life. This work is accomplished via publications and use of other media to inform others of our aerospace medicine and occupational health practices; promoting the incorporation of these practices in educational curricula; and transferring the technologies developed for medical care of space flight crews to terrestrial health care applications such as the use of telemedicine to improve the access to health care in rural and underserved areas and to support medical responses to disaster-stricken areas both in the U.S. and abroad.

The Occupational Health program establishes policies and manages implementation of NASA-wide occupational and environmental health programs and services through the Agency Occupational Health Office located at the Kennedy Space Center. These services include provision of immediate medical care for acute illnesses, accidents and injuries in the workplace; controlling and responding to acute and chronic exposure of employees to toxic materials, hazardous environments and harmful physical agents in the workplace; implementing state-of-the-art wellness programs and preventive medicine programs based on professional practice guidelines of the American College of Occupational and Environmental Medicine.

The JSC has established and is operating a telemedicine system at Star City, Russia to support the U.S. astronauts, flight surgeons, and other personnel in Russia supporting Phase I of the International Space Station (ISS) Program. In addition, JSC is developing a portable telemedicine capability, which will support medical operations activities for the ISS.

Collaborative initiatives with other agencies, academia, and industry will be established to leverage existing technologies and foster development of emerging technologies in telecommunications and information systems as they apply to health care in space flight.

Center and Contractor Support

The JSC and Headquarters are the principal Centers involved in the Aerospace Medicine program. The KSC and Headquarters are the principal Centers involved in the Occupational Health Program. JSC will be assigned Lead Center responsibility for the Aerospace Medicine program, which will be renamed the Space Medicine program. The ARC and LeRC are key Centers in the development of communications and computer technologies for the support of NASA's Spacebridge to Russia, an Internet based telemedicine testbed. The JSC will manage telemedicine efforts in support of medical operations activities for the Human Space Flight Program. The KSC serves as the lead center for management and implementation of occupational and environmental health programs. The ARC serves as the lead center for the telecommunications via the NASA Science Internet. Wright State University School of Medicine and the Texas Medical Center are the major contractors for the Aerospace Medicine program.

MEASURES OF PERFORMANCE

Performance Milestone	Plan	Actual/Revised	Description/Status
Multilateral Medical Policy Board	4th Qtr FY 1997	Under review	Establish a document for the Multilateral Medical Policy Board which validates medical requirements, standards, protocols, and flight rules for all the International Space Station Program.
Executive Council for Health, Environmental Management and Safety	2nd Qtr, FY 1997	Under review	Establish a council for the Agency to ensure Agency-wide uniformity of programs and compliance with externally-mandated laws and regulations.
Commercial Space Center for Informatics and Medical Technologies	2nd Qtr, FY 1997	Under review	Establish a Commercial Space Center for Informatics and Medical Technologies at a leading academic institution to develop partnerships and leverage resources and technologies in the fields of telemedicine, information technologies, and medical technologies

The Aerospace Medicine and Occupational Health program is in the process of redefining criteria for measuring performance. Possible criteria include: the conveyance of technology, protocols and procedures for terrestrial applications; and overall fitness of humans in space and their ability to do productive work by measuring the effectiveness of medical systems, countermeasures, and standards. Possible Occupational Health criteria include documentation of the number of controls instituted for chronic exposures to toxic and or physical and biological hazards, the number of occupational medicine exam abnormalities, the number of life-threatening health risk factors identified and controlled in the employee population, and the number of OWCP claims filed and controverted.

ACCOMPLISHMENTS AND PLANS

The JSC-developed portable telemedicine instrumentation pack (TIP) has been evaluated in several settings, including the Harris County Jail and between the Crow Indian Reservation in Montana and a hospital in Billings, MT. The TIP is currently being integrated with a computer

The Internet-based telemedicine testbed called Spacebridge to Russia, which links several medical centers in the U.S. with several clinical sites in Moscow and integrates Internet tools such as the World Wide Web and video teleconferencing capability to support medical consultations and medical education, were continued. Medical lectures have been exchanged between Baylor College of Medicine and MSU using the Internet.

A space medicine project which focuses on continuous improvement in medical requirements for spaceflight through the development of appropriate laboratory and diagnostic tests, was continued. This project incorporates activities from several JSC programs including the Crew Health Care System for ISS, medical operations activities, and the Human Research Facility. Two space medicine program activities, Spacebridge to Russia and the Global Health Network, were recognized for achievements in the field of Internet applications. They were both named as finalists of the 1996 National Information Infrastructure (NII) Awards.

The Aerospace Medicine program led a Agency-wide initiative to develop a strategic plan on telemedicine. In addition, a comprehensive inventory of NASA telemedicine activities was developed.

FY 1997 plans for the Aerospace Medicine Program include: 1) continuing the Internet-based telemedicine testbed, Spacebridge to Russia; 2) supporting development of the Pan American Health Organization and Global Health Network Internet systems for disaster response planning and for sharing preventive medicine and public health information; 3) developing a network of medical experts for all telemedical consultations for space flight mission support (e.g., flight crew or disaster recovery); 4) developing and in-flight testing of the TIP; 5) continuing comprehensive risk assessment and review of medical requirements for space flight during long duration missions; 6) continuing the Space Medicine Project for the development of medical requirements for research in order to ensure the timely availability of adequate procedures, protocols and countermeasures to maintain and enhance human health and performance during extended duration missions; 7) providing support for operational medical activities for Space Shuttle missions, Phase 1 of the ISS, and the implementation of a comprehensive medical care facility for the ISS; 8) establishing a Joint Medical Policy Board and developing joint medical operations requirements documents with all the ISS partners; 9) continuing the efforts of the Space Biomedical Center; 10) establish a Commercial Space Center (CSC) for Informatics and Medical Technologies; 11) invest in collaborative activities with academia, other agencies, and industry in the application of emerging technologies in communications and information systems to health care; and 12) work closely with medical representatives of the ISS partners in developing medical care requirements, standards, and addressing medical issues.

FY 1997 Plans for the Occupational Health Program include: 1) establishing an Occupational Health Executive Council with a Health, Environmental Management, and Safety subcommittee to ensure Agency-wide uniformity of programs and compliance with externally

mandated laws and regulations; 2) expansion and implementation of an Agency-wide Material Safety Data Sheet (MSDS) system for the cataloging and tracking of toxic, chemical and hazardous substances; 3) development of an Asbestos surveillance system; 4) development of a Lead surveillance system; 5) implementation of an Agency-wide workers' compensation case tracking system for reduction of Agency compensation costs; and 6) development of manpower guidelines for the population supported, exposures, and regulatory requirements.

FY 1998 plans are to continue to provide support to operational medicine activities for the Space Shuttle and NASA/Mir missions and to conduct medical requirements reviews in preparation for the ISS era. It will continue to evaluate new technologies that will support these activities, and ensure appropriate systems are in place to enhance mission success. Activities at the SBC will continue. Support of the Aerospace Medicine Project will continue to ensure the development of medical requirements and assessment of medical risks, establishment of priorities for medical research, and development of medical flight policies in support of all U.S. spaceflight programs including Shuttle, NASA/Mir, the ISS, and future exploration missions. Activities of the CSC for Informatics and Medical Technologies will continue. Efforts with the Multilateral Medical Policy Board and Multilateral Medical Operations Working Group will continue. Investments in collaborative activities with academia, other agencies, and industry in the application of emerging technologies in communications and information systems to health care for space flight will continue.

FY 1998 plans for the Occupational Health Program include: 1) the continued operation of the Occupational Health Executive Council with a Health, Environmental Management, and Safety subcommittee to ensure Agency-wide uniformity of programs and compliance with externally mandated laws and regulations; 2) updating and coordination of an Agency-wide Material Safety Data Sheet (MSDS) system for the cataloging and tracking of toxic, chemical and hazardous substances; 3) monitoring of an Asbestos surveillance system; 4) monitoring of a Lead surveillance system; 5) oversight of an Agency-wide workers' compensation case tracking system for reduction of Agency compensation costs; and 6) phased implementation of manpower guidelines for the population supported, exposures, and regulatory